Leveraging the Radiation-Resistance and Power Efficiency of Nano-Magnetic Logic to Develop More Affordable, Efficient, and Reliable Space Technologies

Completed Technology Project (2013 - 2015)

Project Introduction

I am researching nano-magnetic logic (NML) because it has low power consumption, high density of computing and memory elements, CMOS integration capabilities, and reliability in the presence of radiation. The objectives of my research are to (i) to study and improve the reliability of NML with respect to radiation (ii) implement important algorithms in computer vision and signal processing with NML and (iii) look into different devices and their geometries to reduce the overall power consumption. The objectives are at least partially dependent on majority logic synthesis, which is the synthesis of Boolean functions using the majority operator. NML and many other nano-computing schemes depend on the Boolean majority operator rather than on the AND/OR perspective used to implement CMOS circuits. For fabricated devices, correct functionality can be determined by viewing them with SEM, MFM, or AFM microscopes. Objective (i) will be accomplished by studying the ability of redundant elements in a majority-logic-based Boolean network to reduce the probability that an input error results in an output error. Objective (i) will also be accomplished by simulation, fabrication, and testing of devices with varying geometries and materials. Variation of physical parameters may result in devices that are less prone to error in fabrication and less prone to suffering from radiation and thermal disturbances. The devices will first be tested for functionality, which depends on avoiding fabrication errors. The performance of the devices in high-radiation or high-temperature conditions will be tested subsequently. For objective (ii), the signal processing algorithms will be mapped to a majority-logic form that is suitable for NML. Some of the targeted algorithms are the Discrete Fourier transform and Viterbi encoding/decoding. The computer vision research will focus on using NML to perform non-Boolean computations of computer vision algorithms, and will be accomplished with simulation and fabrication of devices. Using NML in ways other than Boolean computation has been shown to greatly decrease the computation time of some computer vision algorithms, such as the recognition of parallel lines. Objective (iii) will be accomplished by studying the reduction of Boolean expressions that are based on the majority operator. Furthermore, because clocking is the main source of power consumption in NML, (iii) will also be accomplished by simulating the effects of different clocking cycles on NML. A good clocking cycle will require minimal power while avoiding the bi-directional information propagation that can occur with a poorly designed cycle. This research corresponds to the Nanotechnology roadmap, research area number 10, with significant overlap in research area number 11, the Information Technology and Processing roadmap. This research is crucial to space technologies because NML is known to be radiation-hard and low-power, two of the critical objectives of NASA's Nanotechnology roadmap. Aside from these broad objectives, I believe that my research will particularly impact the development of micro-satellites, because these devices depend upon our ability to reduce the size of hardware. NML has a two-fold potential for reducing the size of devices. Firstly, NML has the potential for high-density

Leveraging the Radiation-Resistance and Power Efficiency of Nano-Magnetic Logic to Develop More Affordable, Efficient, and Reliable Space Technologies

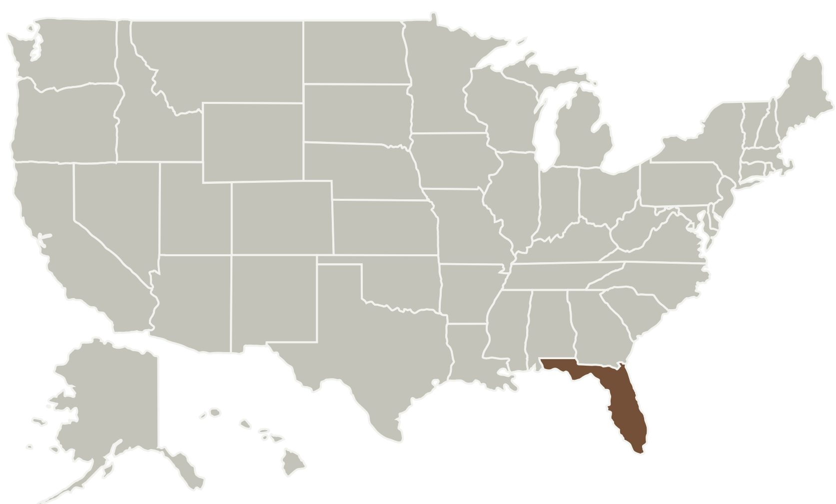
Table of Contents

fabrication. Secondly, the low power consumption of NML will allow us to reduce the size of components dedicated to powering devices. A final reason that this research will be beneficial to micro-satellites is that, for the first time, signal processing algorithms and computer vision algorithms will be implemented with NML. Since all satellites need to communicate with other devices, and since many satellites are designed for the purpose of imaging, such as in surveillance satellites and weather satellites, signal processing and computer vision algorithms are of special significance to micro-satellites.

Anticipated Benefits

This research is crucial to space technologies because NML is known to be radiation-hard and low-power, two of the critical objectives of NASA's Nanotechnology roadmap. Aside from these broad objectives, this research may particularly impact the development of micro-satellites, because these devices depend upon our ability to reduce the size of hardware. NML has a two-fold potential for reducing the size of devices. Firstly, NML has the potential for high-density fabrication. Secondly, the low power consumption of NML will allow us to reduce the size of components dedicated to powering devices. A final reason that this research will be beneficial to micro-satellites is that, for the first time, signal processing algorithms and computer vision algorithms will be implemented with NML. Since all satellites need to communicate with other devices, and since many satellites are designed for the purpose of imaging, such as in surveillance satellites and weather satellites, signal processing and computer vision algorithms are of special significance to micro-satellites.

Primary U.S. Work Locations and Key Partners



Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

Space Technology Research Grants

Project Management

Program Director:

Claudia M Meyer

Program Manager:

Hung D Nguyen

Principal Investigator:

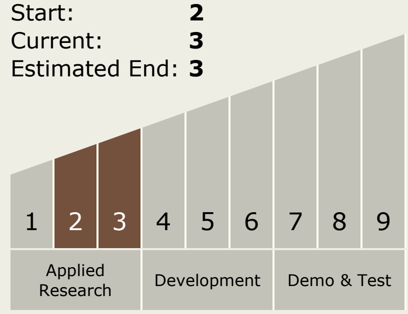
Sanjukta Bhanja

Co-Investigator:

Drew H Burgett

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Leveraging the Radiation-Resistance and Power Efficiency of Nano-Magnetic Logic to Develop More Affordable, Efficient, and Reliable Space Technologies

Completed Technology Project (2013 - 2015)

Organizations Performing Work	Role	Type	Location
University of South Florida-Main Campus(USF)	Supporting Organization	Academia	Tampa, Florida

Primary U.S. Work Locations
Florida

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html

Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
  └ TX11.1 Software Development, Engineering, and Integrity
    └ TX11.1.6 Real-time Software